Dynamic Response of Wheelchair Cushions to the ISO Impact Damping Test

Bummo Chung, MSME
Rehabilitation Engineering Research Center on Wheeled Mobility
Georgia Institute of Technology, Atlanta, GA

www.mobilityrerc.gatech.edu

Abstract

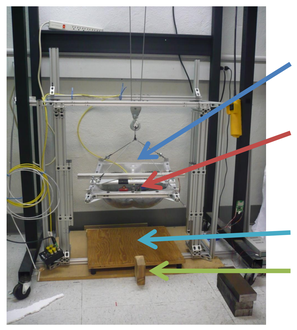
The International Organization for Standardization defines tests that characterize properties of wheelchair cushions (ISO 16840-2). The impact damping test (IDT) characterizes cushions' abilities to **reduce impact loading on tissues** and to **help maintain postural stability**. We performed IDTs on three different wheelchair cushions: 3" elastic foam (EF), 3" viscoelastic foam (VEF), and a 2.5" laminar cushion (LC) with elastic foam surrounding a viscous fluid bladder. Results show that the 3" elastic foam had best abilities to reduce the impact loading on tissues while the 3" viscoelastic foam had the best abilities to help maintain postural stability. In addition, this study suggests **incorporating the peak impact accelerations in the analysis**, **using curve fit parameters to characterize the damping**, and **using impact values in the analysis.**

Aims

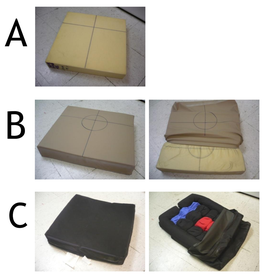
1. Evaluates three wheelchair cushions using the ISO IDT
2. Assesses the feasibility and pertinence of ISO IDT for characterizing the impact damping characteristics of the wheelchair cushions

Methods

Instrumentation



Test Rig
- A rigid cushion loading indenter (RCLI)
- An accelerometer (MMA7260Q, Freescale Semiconductor, Inc.)
- A hinged rigid plate
- A support block.



Wheelchair Cushions
A) 3" elastic foam (EF)
B) 3" viscoelastic foam (VEF)
C) 2.5" laminar cushion (LC) with elastic foam surrounding a viscous fluid bladder.

Experimental Protocol

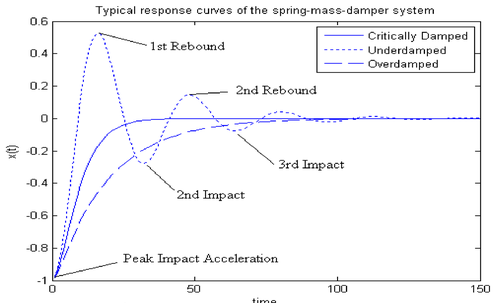
Impact Damping Test

1. Set a hinged rigid plate at a 10° angle by placing the support block
2. Place the cushion
3. Place the RCLI (500 N)
   - Its ischial tuberosities are positioned at the location at approximately 140 mm forward to the rear edge of the cushion
4. Release the support block & measure the acceleration at 200 Hz
5. Unload the cushion for 5 minutes
6. Repeat the step 1-5 for three times

Results and Discussions

ISO Criteria

Subjet	# of Rebound	1st Rebound (m/s^2)	2nd Rebound (m/s^2)	Ratio of Rebound (%)
3" Elastic Foam	1	4.76	1.21	25.91
3" Viscoelastic Foam	2	10.96	4.92	44.77
2.5" Laminar Cushion	2	4.47	3.67	83.72

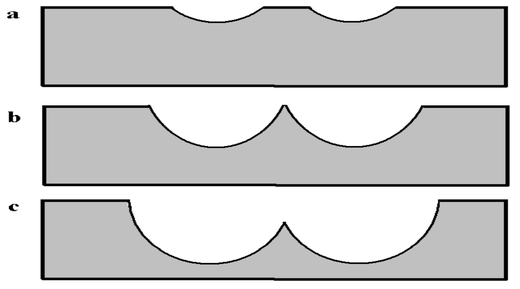


$$x(t) = x(0) \cdot e^{-\zeta \cdot \omega_n \cdot t} \left(\frac{\zeta}{\sqrt{1-\zeta^2}} \sin\left(\omega_n \sqrt{1-\zeta^2} \cdot t \right) + \cos\left(\omega_n \sqrt{1-\zeta^2} \cdot t \right) \right)$$

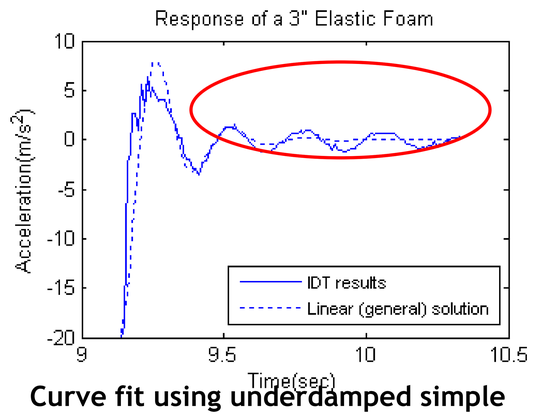
where ζ is a damping ratio, ω_n is a natural frequency, and x(0) is a peak impact acceleration

Suggested Criteria

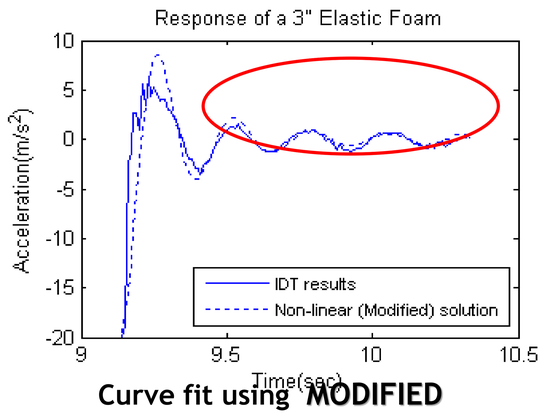
Subjet	Initial Impact (m/s^2)	2nd Impact (m/s^2)	3rd Impact (m/s^2)	Ratio of Impact (%)
3" Elastic Foam	-20.83	-3.18	-1.04	32.93
3" Viscoelastic Foam	-29.18	-7.79	-2.18	27.98
2.5" Laminar Cushion	-19.32	-3.72	-2.56	71.93



Expected contact area during the rebound; a) at the rebound, b) a midpoint between the rebound and the impact, c) at the impact



Curve fit using underdamped simple harmonic solution



Curve fit using MODIFIED underdamped simple harmonic solution

Curve Fit Parameters
x(0) : a peak impact acceleration
ζ : a damping ratio
ω_n : a natural frequency

Parameters used in curve fit

	3" Elastic Foam	
	General Solution	Modified Solution
x(0)	-20	-20
ζ	0.28	0.28 - (0.00130) * t
ω_n	0.25	0.25 - (0.00008) * t

Conclusion

1. 3" elastic foam had best abilities to reduce the impact loading on tissues
2. 3" viscoelastic foam had the best abilities to help maintain postural stability
3. This study suggests **A) Incorporate the peak impact accelerations in the analysis**, **B) Use curve fit parameters to characterize the damping**, and **C) Use impact values in the analysis.**

Acknowledgements

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For more information, please visit www.mobilityrerc.gatech.edu or email to gtg855a@mail.gatech.edu